The Shell Game: Finding Thermal Savings in Residential Retrofit Programs

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ABSTRACT

A successful energy efficiency program reaches the intended audience, results in specific, direct actions to improve energy efficiency and estimates realistic energy savings from these actions. Many factors contribute to the success of a program, including program design, understanding of the target audience, accurate tools for estimating savings, and incentive levels. This paper covers three approaches to achieving thermal savings in existing homes that have been implemented in the Northeast USA and the savings resulting from these efforts as determined through independent impact evaluations. The limits on potential savings as a function of building stock age are also explored.

Impact evaluation indicates that realized savings for all of the evaluated programs fall short of the programs' reported savings. However, the gap between the program reported and evaluated savings varies greatly from one program to the next while the savings as a percent of pre-treatment use is relatively consistent. This result may be related to problems with program design, analysis tools and/or characteristics of the target population and funding levels.

The paper covers the following topics:

- Comparing and contrasting the key aspects of the program design
- Discussion of various metrics for measuring savings
- Presentation of results from independent impact evaluations
- Analysis of the evaluation results in the context of the program designs
- Exploration of the reasons that program-reported energy savings are not being achieved

The final section will cover recommendations to provide guidance for evaluators and program staff working within the residential market.

Introduction

Residential energy consumption constitutes a substantial portion of the overall energy portfolio in both the US and the EU. The recent focus on climate change and carbon dioxide emissions has turned attention to the reduction of fossil fuel use and the thermal efficiency. Some entities, such as Build America, suggest that thermal savings in the range of 30% of consumption can be realized.

However, achieving thermal savings in the residential retrofit market can be a difficult enterprise for a wide variety of reasons, some of which are briefly described below.

- Savings per home are relatively small and highly variable, and site visits are expensive.
- Homes have no facility manager; homeowners often have little understanding of their energy consumption and what types of efficiency upgrades are the most appropriate for their homes.
- The wide variation in homes' age, condition, size, and construction makes application of a prescriptive approach untenable.
- Market barriers, such as capital costs, competition for the available capital and a return on investment, involve not only the energy savings that might accrue but also the eventual value the market may place on those improvements when the home is eventually sold.

These factors make it difficult to design and deliver residential retrofit programs. Nonetheless, efficiency programs designed to target this diverse population and achieve thermal savings have been in operation since the 1980's and are still being implemented in many jurisdictions.

From a planning perspective, we want to be able to assess the savings potential that can be achieved and the strengths and weaknesses of the possible program designs. There are four major drivers of the savings potential: 1) age and thermal characteristics of the housing stock, 2) customer education and technical assistance, 3) funding for measure installation and 4) the quality of the installation.

Review of residential retrofit program in the northeastern U.S. provides some useful insights into past performance and future directions. The history of program implementation and evaluation in this sector provides a wealth of information for assessing the effectiveness of program delivery mechanisms and to develop realistic expectations of the costs and savings that can be achieved.

The single family residential programs operating in this region fall into three broad categories: market based programs primarily implemented by contractors, direct programs with audits conducted by in-house staff and contractor assistance and low income programs that fully fund measures using a variety of sources including a significant contribution from the federal government. While each of these strategies has strengths and weaknesses, impact evaluations indicate that the end results are fairly similar. For large scale, mature programs, program reported savings are sometimes 25% or more of household consumption on average while evaluated savings are closer to 15%. This gap between program reported and evaluated savings suggests that impact evaluation is a necessary tool to ensure that the programs are operating as intended and to provide feedback and support to program implementers.

The following sections include a comparison of program structures and incentives, evaluation methods and metrics, impact evaluation results, savings potential and program delivery mechanisms, and conclusions.

Comparison of Efficiency Programs

The northeastern U.S.[1] is demographically and geographically diverse and includes some of the most urban and rural areas of the United States. Heating degree days (ºF) for this area range from 4,590 to over 10,000 and all of the states have residential efficiency programs that target improvements in thermal and HVAC systems in existing homes. In order to ensure a valid comparison, this analysis was confined to programs in the northeastern US region where housing stock and other market characteristics are relatively similar. Furthermore, only programs that have undergone rigorous impact evaluations were included.

All of these programs offer an initial assessment of needs from a trained auditor. In market based programs, contractors provide a home assessment to the homeowner and it is at the homeowner's discretion to follow the recommendations and complete installations. Incentives are offered both to the homeowner and the contractor. Under the direct program model, the utility or agency offers an audit, assistance with finding a contractor and direct incentives to the homeowner. Low income programs generally provide audits for eligible dwellings, select which measures have the greatest benefit within funding constraints, and arrange to complete the work at no cost to the participant. Low income programs also rely on Federal Weatherization Assistance (WAP) funding. These funds are distributed to the states and the states generally use sub-grantees to provide the actual services.

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[1] The northeastern region referenced in this paper consists of the six New England states (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont) and New York State.

Qualified contractors are a key component of all three types of programs. Market based programs generally provide a list of qualified contractors for major upgrades such as insulation, air sealing and heating system replacement. The audit provider may be one of the listed contractors but the homeowner is not obligated to use that contractor. Direct programs may also offer a list of qualified contractors. For low income programs, the WAP sub grantee or utility that completes the audit may undertake the upgrades using in-house personnel or may use an outside contractor, but the homeowner or renter is not involved in the decision. Many of the programs require Building Performance Institute certified auditors and accredited contractors.

Finally, all three types of programs provide funding for efficiency upgrades. In market based programs, the funding is provided in the forms of direct incentives and/or loans with below market rates. The incentives for equipment replacement are usually set to cover the incremental cost over standard efficiency equipment. Upgrades such as insulation might be set at a percent of project cost with a not-to-exceed cap. For instance, for the New York State Energy and Research Development Authority (NYSERDA) the cap is $3,000 while in Massachusetts it is $2,000 (NCSC 2013). Incentives are also offered to the contractor.

A potential key difference between market based and direct programs is the real or perceived conflict of interest. Utility or agency staff members are a disinterested party with no financial interest in the completion of efficiency projects. However, a contractor who is both conducting the audits and selling her services may have a different perspective.

Table 1 provides a list of the residential retrofit programs offered in the northeast that have undergone rigorous impact evaluations in the recent past. The table identifies the delivery entity and the program year most recently evaluated. As can be seen, we were able to find recent evaluations for seven of these programs.

Table 1: Comparison of Program Characteristics

Program	Delivery Entity	Service Territory	Program Type	Program Year of Most Recent Impact Evaluation
Home Energy Services (HES)	Multiple Program Administrators	Massachusetts	Market Based and Direct Programs	2010/early 2011
Residential Retrofit Market Rate Program (RMR)	Vermont Gas (VGS)	Vermont	Direct Program	2008-2010
Residential Retrofit Low Income Program (RLI)	Vermont Gas	Vermont	Low Income	2008-2010
Home Performance with Energy Star (HPwES)	Efficiency Vermont (EVT)	Vermont	Market Based	2008-2010
EmPower	NYSERDA	New York	Low Income	2007-2008
Home Performance with Energy Star (HPwES)	NYSERDA	New York	Market Based	2007-2008
EnergyWise	National Grid	Rhode Island	Market Based	2010

One of the major differences between market based/direct programs and low income programs is that only partial incentives for recommended measures are offered through the market based programs, while low income programs strive to fully fund a more comprehensive retrofit. However, WAP is limited by regulation to $6,500 per household and each state has a set amount of funding. Thus the funding limit affects how many homes can be served in a given year. For instance US Department of Energy (DOE) Fiscal Year 2012 funding for the WAP program in Vermont was $14,130,828 (WAP 2014). The allowable cost in 2012 was $6,500 per home using DOE Funding (NASC 2013). Even assuming that funds were leveraged 100%, the funding cap limits services to 2,174 homes that can be treated.

While low-income projects often fund the entire project, market based programs incentivize a portion of the total cost of the project. There are two approaches commonly used to set incentives for different types of measures. The first approach incentivizes a certain percentage of the cost associated with completing the work. Insulation and air sealing is commonly incentivized using this approach. Table 2 provides a comparison of incentive rates offered through market based programs utilizing this approach.

Table 2: Comparison of Incentive Levels

Program	Service Territory	Measures	Percent of Cost Incentivized	Maximum Incentive
HES	Massachusetts	Shell Measures	75%	$2,000
RMR	Vermont	All Measures	33%	$2,100
EnergyWise	Rhode Island	Shell Measures	75%	$2,000
HPwES	Vermont	All Measures	Performance Based	$2,100
HPwES	New York	All Measures	10%	$3,000

Market based programs may not be restricted by the number of homes they can serve. However, as can be seen from Table 2, the maximum incentive per home is almost half the amount of incentives available through WAP.

A second funding strategy commonly is to provide a fixed rebate for completing certain measures. This approach is often used for equipment upgrades at time of replacement and the incentive levels are set to cover the incremental cost associated with upgrading from the standard efficiency equipment to high efficiency equipment. Space and water heating replacements are often incentivized in this manner

It should be noted that some market rate programs also provide loans at below market rates. However, since the market does not necessarily value efficiency improvements, the homeowner has no guarantee of recouping the investment.

Evaluation Methods and Metrics

There are many metrics used to assess the overall performance of residential retrofit programs. At the household level, evaluators often rely on a few key indicators:

1. Average savings per home as a percentage of pre-install use
2. Realization rates (program reported savings/evaluated savings)

3. Average project costs per home (to estimate the scope of the work)

These metrics provide insight into how the program is operating in the field. The average savings per home as a percent of pre-installation consumption is a useful indicator in that it allows for comparison between programs on an even basis. The realization rate is a direct measurement of the quality of the estimated program reported savings, but does not actually provide a way to compare savings across programs and across delivery mechanisms. The average project cost per home is essentially a proxy for the scope of the work; deep retrofits including heating system replacements and extensive shell improvements will cost substantially more on a per home basis than programs that are more focused on promoting the installation of one or two specific measures.

Impact evaluations involving billing analysis, engineering models or some combination of the two are used to estimate these metrics. The California Evaluation Protocols (TecMarket Works, 2006) identify billing analysis and simulation models calibrated to monthly billing records as meeting the standards for enhanced rigor. In contrast, simple engineering models and normalized annual consumption models are considered to be basic rigor. Billing records are critical to the ability to develop reasonable estimates of energy savings at the household level.

Comparison of Impact Evaluation Results

In order to have a valid comparison across programs, we identified programs where a similar level of rigorous evaluation was completed. All of the evaluations used in the comparison used billing analysis with pre and post consumption to estimate savings. The table below provides a comparison of the program evaluated program savings as a percentage of pre-participation usage. The evaluated savings range from 9% to 22% of pre-installation consumption.

Table 3: Comparison of Pre-Installation Consumption and Program Savings

Program	State	Program Type	Average Pre Install Use (Therms/ year)	Program Reported Savings (% of Pre Install Use)	Evaluated Savings (% of Pre Install Use)	Overall Realization Rate
HES*	MA	Direct and Market	1,195	15%	12%	76%
VGS RMR	VT	Direct	1,255	26%	22%	89%
VGS RLI	VT	Low Income	882	26%	16%	62%
EmPower	NY	Low Income	1,090	13%	9%	70%
HPwES	VT	Market Based	915	35%	18%	51%
HPwES	NY	Market Based	1,055	25%	16%	65%
EnergyWise	RI	Market Based	1,168	13%	13%	99%

*Includes only insulation and air sealing measures

Potential Energy Savings

The current programs are increasing the thermal efficiency of the housing stock in the northeast states by from 9% to 22%, as can be seen above in Table 3. The potential identified by the industry suggests much higher savings of 30% to 50%, e.g., projections by the Build America Program. Only the VGS program is even approaching the lower bound of this potential. This program is specifically targeted to high use "residential customers that consume in excess of 50,000 BTU/ft2s per square foot [158 kWh/sqm.a] per year," suggesting that these homes have a higher potential for savings than many others (WHEC & GDS, 2013 b).

There are two characteristics that essentially define the potential for improving residential housing efficiency in the northeastern US. The first is the existing housing stock and the level additional efficiency that can be reasonably achieved. The second is the availability of technical and financial assistance to assist homeowners in achieving those savings. In addition, two program-related issues can have an impact on the ability of homeowners to realize the expected savings on their bills: 1) the use of engineering models alone to estimate savings can systematically overstate savings and 2) the quality of the installation has a major impact on the realized savings.

These four topics are explored in more detail below, followed by a discussion of the current plans in the EU to address energy efficiency in the residential market.

Northeast US Housing Stock

The age and construction of a home are two of the important factors that determine the savings potential in a given location. Potential savings from residences can be estimated based on when and how they were constructed. In the Northeast US, very few homes were well insulated prior to 1940. Very old homes may have post and beam construction, and balloon framing was common from the late 1800's forward. From 1940 through 1950 there was a shift toward "western" platform construction, with fewer bypasses, and insulation became more common. Currently, most single family residential construction is platform framed.

The 1960's and 1970's saw the widespread adoption of more efficient building practices and the federal Energy Policy and Conservation Act in 1975 introduced energy efficiency standards for the manufacture of major appliances such as heating equipment. The Arab oil embargo in the mid 1970's also created a driver toward higher levels of insulation and tighter construction practices. The trend toward more efficient housing has continued through the present time.

A consequence of this history is that there are greater savings opportunities in older housing stock than in new housing stock. There are of course some caveats to this observation. The house built in 1938 is likely to not have the original heating equipment, due to equipment life, and the replacement would have met the federal efficiency standards when it was purchased. Houses are also periodically updated and these updates may have included additional insulation, better windows, weatherization and improved equipment. However, in general there are still more savings opportunities in older homes in the Northeast US than in newer ones.

The U.S. Energy Information Administration does a periodic Residential Energy Consumption Survey (RECS), last completed for 2009. The survey data includes a breakdown of the decade that housing units were built with a starting point of pre 1950. Using the RECS data and an assumed percentage of potential savings from housing depending on the year of construction, Figure 1 provides a low medium and high projection of the potential savings from homes in the northeastern states.

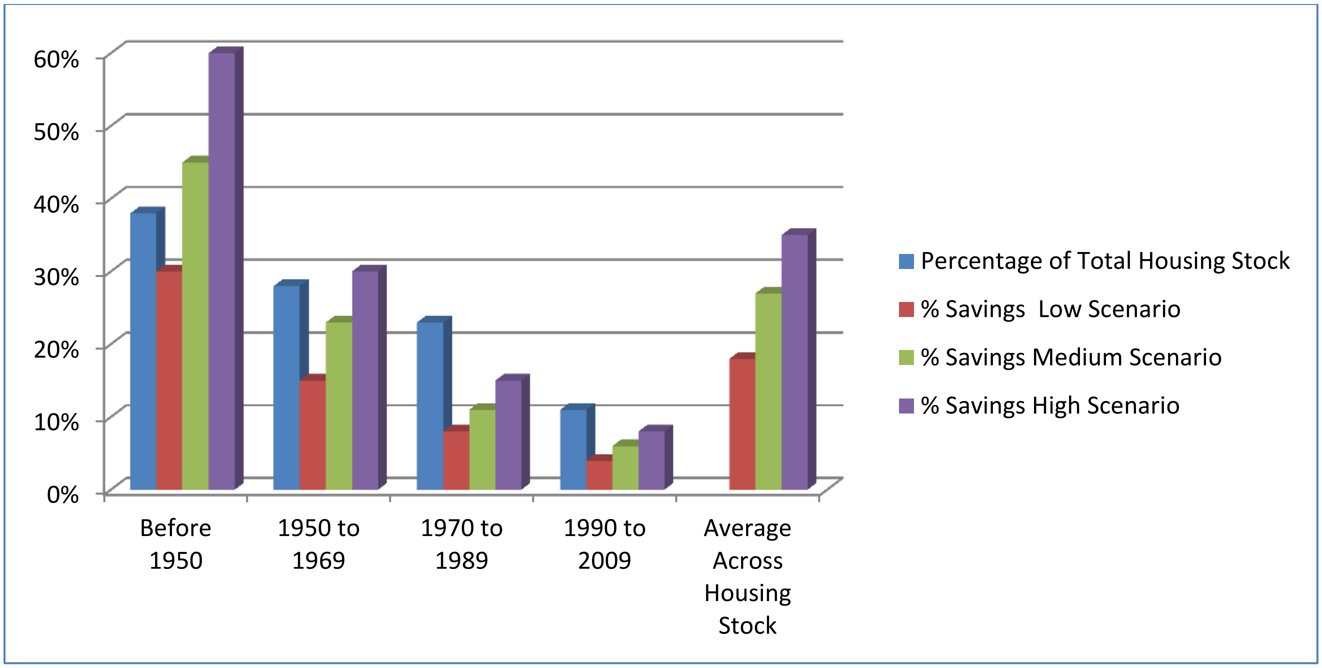

Figure 1: Savings Potential by Age of Home Northeast US

The high scenario assumed deep retrofits and takes into account the potential for savings given the prevalent construction during the period. Using these assumptions, the high scenario suggests that 35% of the pre-install consumption can be saved on average. The low projection of 18% average savings is very close to the 16% that evaluation studies show programs are achieving in the region for envelope improvements. The Build America Program has a goal of improving the efficiency of existing homes by 30-50%. To achieve that level of savings requires deep retrofits that are not currently widely adopted by the market.

Project Costs

One of possible reasons for the difference between the programs' reported and evaluated savings is that the level of available subsidies is inadequate to overcome the initial cost barriers to comprehensive installation. A comprehensive retrofit will likely require some combination of additional insulation, air sealing, heating system upgrades and window replacement or treatment. It can be difficult for market rate programs to be comprehensive.

A deep energy retrofit pilot in Massachusetts completed by the US Department of Energy and National Grid, Inc. found that the average cost for completing work on a single family home was $34.6/ft^2$ (USDOE 2014). A modest single family home is 1000 ft^2 (or about 100 m^2), so this translates into at least $35,000 or €25,000. Many older home in the Northeast US with substantial savings opportunities are closer to 2,000 ft^2 (roughly 200 m^2) or larger. In the pilot study, incentives ranged from $35,000 to $42,000. In comparison the maximum incentive levels available in the Northeast are in the range of $2,000 to $5,000 dollars. According to the US Home Performance with ENERGY STAR fact sheet, the average costs of projects range from US$5,600 to US$8,500 in the state of New York (ES 2011).

With total project costs of about 25% of the deep retrofit costs for the pilot project, it seem clear that that the current programs in the Northeast US are not achieving the level of investment necessary for deep retrofits. These findings suggest that the technical and financial assistance provided to homeowners is not sufficient to achieve deep retrofit savings.

Use of Engineering Models

A critical consideration is the operational characteristics of the residence. Operational characteristics include a large variety of homeowner decisions that directly impact the amount of energy used in the residence such as thermostat settings, setbacks, when the heat or cooling is turned on and off for the season, domestic hot water temperature, how clothes are washed and dried, etc. These small life style choices affect energy use and by extension, the potential savings.

The seven programs discussed in this paper use engineering modeling to estimate savings. Thirty years of experience demonstrates that modeling residential homes is a complex exercise and modeling alone tends to systematically overestimate the household consumption and savings from energy efficiency measures.

Retrofit programs that effectively consider pre-installation a component of savings estimation usually have better realization rates than those that rely solely on engineering estimates. Another significant feature of the VGS RMR program is that savings estimates are routinely checked against consumption to insure that they are reasonable. While the targeting of high use customers likely results in a higher savings as a percentage of pre-installation use, the consideration of the operational characteristics of the home is responsible for the program's high realization rate.

Quality of the Installation

If contractors are cutting corners or failing to use available diagnostic equipment to check the quality of the installation, savings will be compromised. The ability to diagnose and understand the actual heat loss in homes has radically improved in recent years as equipment such as blower doors and infrared cameras have become commonly available. Blower door assisted air sealing takes the guess work out of identifying where the air leaks are occurring and conducting a pre- and post-retrofit blower door test allows us to quantify the improvement. Infrared imaging can be used to demonstrate where the primary sources of heat loss are.

Evaluation of this key aspect of program implementation is commonly missed, as it is generally not included in process evaluations and the billing analyses conducted for impact evaluation do not identify the specific shortcomings of the program delivery. Good installation practices, such as ensuring that all air leaks are sealed and that insulation properly covers the entire area to minimize thermal bypasses, are well established by organizations such as the Building Performance Institute[2] and the Institute for Sustainability[3]. However neither impact nor process evaluation for the programs reviewed for this paper provide insights into the quality of the actual work done through the programs. More research is needed on this topic.

Comparison to Current EU Strategies and Status

As outlined in a memo by the European PPP Expertise Centre (EPEC), the EU is experiencing a shift in funding towards residential energy efficiency. Historically, Regional Policy has financed EE

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[2] http://www.bpi.org/Web%20Download/BPI%20Standards/BPI%20104%20Envelope%20Professional%20Standard%20%2808-03-10%29.pdf

[3] http://instituteforsustainability.co.uk/guidesummariesa.html#6

investments only in public and commercial buildings. However as a result of a regulatory amendment in 2009, up to 4% of the national European Regional Development Fund (ERDF) allocations may be used for energy efficiency improvements in the private residential sector. Furthermore, another regulatory amendment was passed in 2010 which extended the use of financial engineering instruments to energy efficiency and renewable energy in buildings, including existing housing (ICF 2014). Since residential buildings represent 75% of the total housing stock in the EU in terms of surface area, this segment of the building stock represents a significant source of potential savings. Furthermore, a large share of the building stock in Europe was built before the 1960s when building regulations were limited. This type of housing stock generally has some of the largest energy-saving potential (EPEC 2014).

In 2011, the European Commission completed a report titled Technical Guidance financing the energy renovations of buildings with Cohesion Policy Funding. As part of this report, guidelines and considerations are outlined for member authorities as they begin to implement programs in individual EU Member States (MS_s). The table below provides a comparison of some of the features of the Home Performance with Energy Star (HPwES) program implemented in the United States as compared to the guidelines outlined in the technical guidance report.

Table 5: EU and US HPwES Guideline Comparison

	EU Cohesion Funding	HPwES
Funding Increases Proportional to Overall Savings	Yes	Yes
Low Interest Financing is Available	Yes	Yes
Baseline Definition	Prevailing Energy Performance Requirements	Pre-existing thermal efficiency or current federal equipment standard
Supports Single Measure Installation	No	Yes
Incentivizes Lighting	No	Yes
Requires Energy Audits	Yes	Yes

Like in the Northeast US there are inherent characteristics to the single family housing in any given region of the European Union (EU). The Report of the Federal Government of Germany to the EU Commission on the long term strategy for the mobilization of investment in the renovation of the national building stock provides the distribution of German residential dwelling units by age of the building. The same type of analysis used to evaluate potential savings in the northeast was conducted to estimating the potential savings for Germany. The analysis used the same assumptions regarding the potential savings by age group. The results are shown in Figure 2.

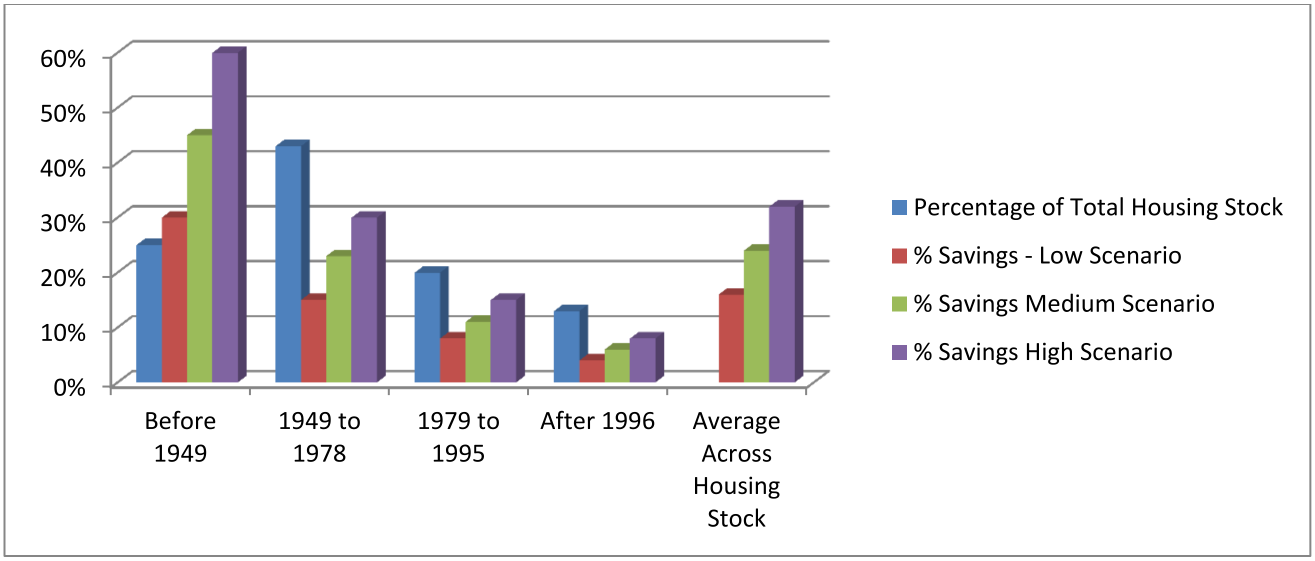

Figure 2: Savings Potential by Age of Home Germany[4]

The calculation indicates that a home performance style program could have a similar impact on residential energy consumption in Germany as was found in the Northeast US. However, there is a high degree of uncertainty with this analysis as the percent of savings has not been established through billing analysis of existing programs in Germany. Differences in the initial levels of efficiency, building construction practices and operational characteristics would all affect the achieved savings. In addition, program delivery details, and incentive levels and cultural differences are likely to affect the penetration of measure installations and, thus, the household savings.

Conclusions

As the EU and many jurisdictions in the US move toward the market based home performance model to achieve thermal savings in residential buildings, it is a good time to review our experience with residential retrofit programs to date. Rigorous impact evaluation has shown that the savings from seven residential programs in the northeastern US are quite similar as percent of pre-treatment usage. However, the evaluated impacts show savings in the range of 15%, falling far short of the stated goal of 30 to 50% proposed by some entities.

The home performance model, direct programs and low income programs have many similarities in terms offering energy audits at the starting point, the range of measures, the scope of the work as estimate from per household costs. The differences lie in the operational aspects of the program: who conducts the audit, who selects the specific measures to be installed and how the work is funded. However, even with these differences, the program savings are within a fairly narrow range, with the exception of the Vermont Gas program which focused primarily on high use customers.

This result demonstrates that rigorous billing analysis provides a reproducible result across similar programs. In addition, the method provides an accurate measurement of the real reduction in energy intensity, which is a critical component of measuring climate change impacts. It also suggests that programs providing nearly identical services and incentives in regions with common building stock

[4] *Mitteilung der Regierung der Bundesrepublik Deutschland an die Kommission der Europäischen Union* (includes multi-family housing) p 7.

can rely on evaluations of other, similar programs to benchmark their savings estimates. The benchmark can be used to ascertain whether savings estimates from engineering algorithms are reasonable at the program level.

These programs do not seem to be generating deep retrofits as indicated by project costs in the range of $6,000 to $8,000 as compared to the $35,000 suggested by the deep retrofit pilot project conducted by the DOE and National Grid. This outcome is likely due to the high expense to homeowners and/or the need for additional technical assistance. The program design will need to be modified to move participants toward deep retrofits.

Some of the key lessons from home performance implementation to date are summarized below.

- Engineering algorithms do not account for many of the operational characteristics of a household and solely relying on engineering estimates can introduce systematic errors that overstate savings as can be seen in many of the programs discussed here.
- Rigorous impact evaluation based on billing analysis is needed to determine actual program savings, as engineering modeling alone is insufficient.
- The home performance program design as currently implemented in the US may need to be modified if savings greater than 15% of pre-installation consumption are desired.

One area that could use more attention is the quality of installation of measures; this key aspect of the program delivery can substantially affect the realized savings. Research is currently in progress for the NY HPwES and results from these evaluation activities may be useful for program implementers to improve installation practices.

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